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Scrutinising reconstructions of dust flux to the ocean using ^{232}Th and ^{230}Th in seawater: a 1D modelling approach

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Mineral dust deposition over the ocean is important for ocean elemental budgets, biogeochemical cycles and dust-climate feedbacks. However, direct observation of dust deposition rates is challenging due to the vast and remote nature of the oceans. Geochemical measurements may provide a useful indirect measure of dust deposition by constraining the supply rate of dust-derived elements to the ocean.

Over the last 15 years, measurements of dissolved thorium isotopes in seawater have been used to quantify dust fluxes in most ocean basins; this approach uses the well-constrained radiogenic production of ^{230}Th to estimate the removal rate of lithogenic^{232}Th. When combined with estimates of thorium solubility, such measurements quantify dust and trace element fluxes to the ocean. However, this approach has been hindered since its inception by the observation of strong apparent vertical increases in calculated ^{232}Th (and dust) fluxes with water depth. Such increases are not consistent with dust dissolution near the ocean surface and their unknown origin severely limits the utility of thorium as a quantitative tool. Given their ubiquity, we investigated whether apparent increases in ^{232}Th flux with depth could be an artifact of the method of calculation. We applied a well-known one-dimensional reversible scavenging model to produce idealised profiles of both ^{230}Th and ^{232}Th, and used that model to test existing approaches to flux assessment and to develop an improved method.

Our results indicate ^{232}Th is released from dust over the upper few hundred metres of the water column. In this depth range, traditional use of integrated ^{230}Th residence times (t_{230}) may be reasonable because the source terms of both isotopes share a similar profile. At greater water depths, integrated t_{230} overestimates ^{232}Th flux by a factor that approaches 2, due to the different depth distributions of ^{232}Th and ^{230}Th addition. We suggest a new approach to calculate t_{230} which relies on in-situ concentrations of ^{230}Th at each depth. Using this approach yields ^{232}Th fluxes that are broadly constant with depth and which more accurately capture the true ^{232}Th flux. We apply our new approach to reassess ^{232}Th fluxes from published thorium profiles in different ocean basins.